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# Hood System Design for Capture of Process Fugitive Particulate Emissions

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16. ABSTRACT The paper discusses a technical manual whose emphasis is on the design and evaluation of actual hood systems used to control various fugitive particulate emission sources. Engineering analyses of the most important hood types are presented to provide a conceptual understanding of the design process, consisting of identification of source parameters, calculation procedures, and techniques for evaluating hood performance. Some of the design techniques have been introduced in technical papers by Hatch Associates and have been formalized in this manual. Case studies of actual hood systems not only illustrate the application of these design methods, but also identify their limitations. Several of the case studies are from the files of Hatch Associates and provide unique insight into the diagnosis of an existing system. The purpose of the manual is to provide regulatory officials with a reference guide on the design and evaluation of hood systems to capture process fugitive particulate emissions. Much of the hood design information is of necessity analytical, based on a mathematical or engineering approach. However, every effort has been made to explain the physical processes in qualitative terms and to separate the formal equations.

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# Hood system design for capture of process fugitive particulate emissions

*Reference guide on the design and evaluation of secondary hood systems to capture process fugitive particulate emissions*

By **EDWARD R. KASHDAN**, **DAVID W. COY**, and **JAMES J. SPIVEY**, Research Triangle Institute, Research Triangle Park, N.C.; **TONY CESTA**, and **HOWARD D. GOODFELLOW**, Hatch Associates Ltd., Toronto, Ontario, Canada; and **DALE L. HARMON**, Office of Environmental Engineering and Technology, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

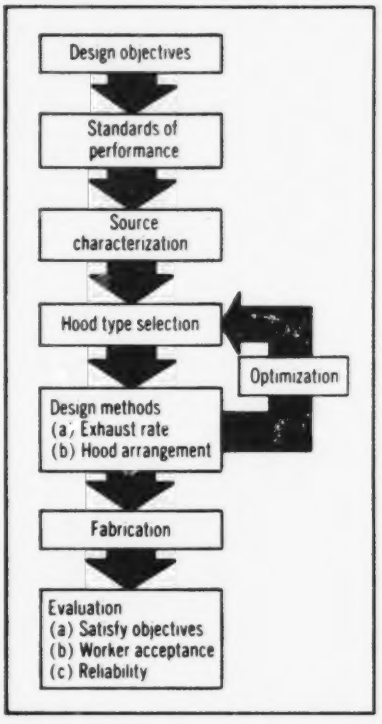
**Process fugitive particulate** emissions have been defined as "particulate matter which escapes from a defined process flow stream due to leakage, materials charging/handling, inadequate operational control, lack of reasonably available control technology, transfer, or storage."[1] Secondary hood systems consisting of enclosures, local hooding, or remote hooding are the practical means of capturing these emissions. Once captured, the gas stream can be ducted to high efficiency air pollution control devices. Frequently, the capture efficiency of the hood is far less than the removal efficiency of the control device. Emissions missed by the hood usually escape to the atmosphere.

Considering the diversity of sources classed as process fugitives, it is not surprising that the design of secondary hood systems varies greatly; large ranges are found in size, exhaust rate, and arrangement. Regulatory officials responsible for reviewing hood systems for either existing or planned sites face a difficult task. The behavior of process fugitive particulate plumes is complex. Process equipment interference may change plume dimensions and location, and in-building air currents may cause plume drift. As a result, the interaction of the hood and plume is not always predictable. Moreover, most of the traditional industrial ventilation texts do not consider process fugitive sources specifically. These texts have emphasized general design rules rather than a thorough understanding of hood design or the limitations of design methods.

This article presents the design and evaluation of actual hood systems used to control various fugitive particulate emission sources. Engineering analyses of the most important hood types are presented to provide a conceptual understanding of the design process, which consists of identification of source parameters, calculation procedures, and techniques for evaluating hood performance.

Case studies of actual hood systems not only illustrate the application of these design methods but also identify their limitations. General hood capture system design considerations are discussed. An example illustrates the application of specific design methodology to low level fugitive emissions from a primary copper converter.

1 Summary of hood design process.




## Design considerations

The hood designer's job is often viewed as nothing more than devising some convenient hood arrangement and estimating the required exhaust rate. These are actually

[1] *Superscripts refer to numbered references at end of article.*

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## General design principles for hood systems

- **Design objectives**
  All hoods must be designed to satisfy certain standards of performance.
- **Selection of hood type**
  The nature of the process fugitive emissions and access to the process determine the selection of the hood.
- **Source characterization**
  A thorough knowledge of the process source parameters is essential to the successful design of a hood system.
- **Exterior hoods**
  Nonbuoyant sources—Required exhaust rate is based on contour surface and capture velocity.
  Buoyant source—Required exhaust rate may be determined from momentum considerations.
- **Receiving hoods**
  Inertial source—Best hood arrangement is such that hood opening coincides with particle trajectory.
  Buoyant source—Local capture requires knowledge of heat generation rate and gas temperature. Remote capture requires estimation of the direction and quantity of thermally induced air flow.
- **Enclosures**
  Inertial source—Required exhaust rate is based on air flow induced by the motion of the materials and consideration of dust producing mechanisms.
  Buoyant source—Design is based on considerations similar to local receiving hoods.

*Adapted from Heneon (1963).*

only intermediate steps in a well considered design process (Fig. 1).

The starting place for hood design is defining the design objectives clearly in quantitative terms. Once the objectives are understood and agreed upon, a thorough characterization of the process fugitive source must take place. Not only is a knowledge of the physical characteristics of the plume necessary during both average and peak conditions, but the process source should also be examined regarding measures to reduce emissions, planned process changes, and concurrent processes (equipment interference and in-building air currents, etc.) in the plant. Selecting a suitable hood type follows. At last, design methods come into play to provide hood dimensions and to estimate the exhaust rate required to meet the design objectives.

Implicit in applications of the design methods are evaluations of alternative hood arrangements and required exhaust flow rates. Technical and economic evaluations are used for optimization in the hood capture system design process. The designer is also responsible for ensuring that the hood system after installation is reliable and accepted by all personnel.

Hood systems are designed for one or more objectives. Typically, the objective is to reduce workplace contaminant concentrations, to reduce air pollution emissions, or to recover a product. In any case, it is essential to quantify the objectives in terms of standards (*e.g.*, to meet a workplace exposure standard, to reach an acceptable opacity level for particulate matter escaping through roof vents, or to achieve a desired level of visibility in the plant). These standards then determine the expected performances of the hood systems. Hood systems, planned or existing, must be evaluated with reference to the design objectives.

Attention now turns to the emission source to be controlled. Consideration should first be given to the possibility of eliminating or modifying the contaminant generation process itself. Even when hooding is used, changes to the process could reduce the amount of contaminant generated or simplify the hood design problems by altering the way that contaminant is dispersed. By the same token, the possibility of future changes in the process conditions must be considered as well. No hood design can accommodate increases in emission volume flow rates far in excess of the levels it was originally intended to control. Too frequently at this point, due consideration is not given to concurrent processes and activities in the plant. Inasmuch as every hood system is affected by air flow patterns within the building, drafts from opening bay doors or from various thermal processes can degrade hood performance.

Stationary and/or moving overhead cranes are another disruptive factor for some hood systems that may alter plume dimensions or disperse the plume beyond hood boundaries. Recognition of these factors during source characterization provides the opportunity to design a hood system that can satisfactorily accommodate some disruptions or to take steps to reduce their impact on hood system performance; *e.g.*, use of partition walls to reduce cross drafts.

Process fugitive particulate sources may be classed broadly as buoyant, nonbuoyant, and inertial. Buoyant sources are hot processes (many are 1000 C or greater), giving rise to plumes with initial velocities on the order of 3 m per sec. Nonbuoyant sources are cold processes, or at least not very hot; for the nonbuoyant source, the plume will not exhibit strong plume rise and is likely to be deflected easily even close to the source. Inertial sources are nonbuoyant and in addition consist of high concentrations of coarse particulate matter. The motion of the particulate matter entrains additional air and determines the behavior of the inertial plume.

### Hood classifications

Although many names are used to classify hood systems, hoods are most conveniently classified in relation to the emission source they control. Three hood types may be distinguished: enclosures, exterior hoods, and receiving hoods. Enclosures completely surround the source of emissions. Obviously from

the standpoint of capture efficiency, enclosures are the preferred method of control because escape of emissions is limited to leaks through openings. However, enclosures are not always suitable, especially in cases requiring ready access to the process source.

Exterior hoods (also referred to as perimeter and captor hoods) are so called because they are exterior to the source. Exterior hoods function by inducing air flow toward the suction opening. Because the "reach" of such hoods is limited, exterior hoods are always local; *i.e.*, close to the source.

Receiving hoods are intended to act as receptors to particulate plumes that, by virtue of the process source, possess significant motion. Receiving hoods may be local or remote from the source (a canopy hood is one kind of receiving hood). An important special case is a hood system that uses air jets to assist in the capture of particulate emissions. This design in this article is termed an "assisted exterior hood" (push/pull hood) because the hood system (not the process) directs the motion of the particulate plume.

Selection among the three hood types is limited to the above source classification. Other factors limiting the selection include: planned or existing site, access to the process, amount of clear space around the emission source, and constraints on operating costs and/or fan capacity. A summary of the general principles for designing the different hood types is provided in the accompanying sidebar.[4] From the standpoint of hood capture efficiency, enclosures are always preferable to local hoods, which in turn are preferable to remote hoods. For large scale inertial sources (*e.g.*, materials handling), enclosures are practically the only choice. Nonbuoyant sources most often are controlled by local hoods. Remote hoods may be used on buoyant sources and frequently are. When planning controls for a buoyant source, however, one should consider enclosures or local hooding.

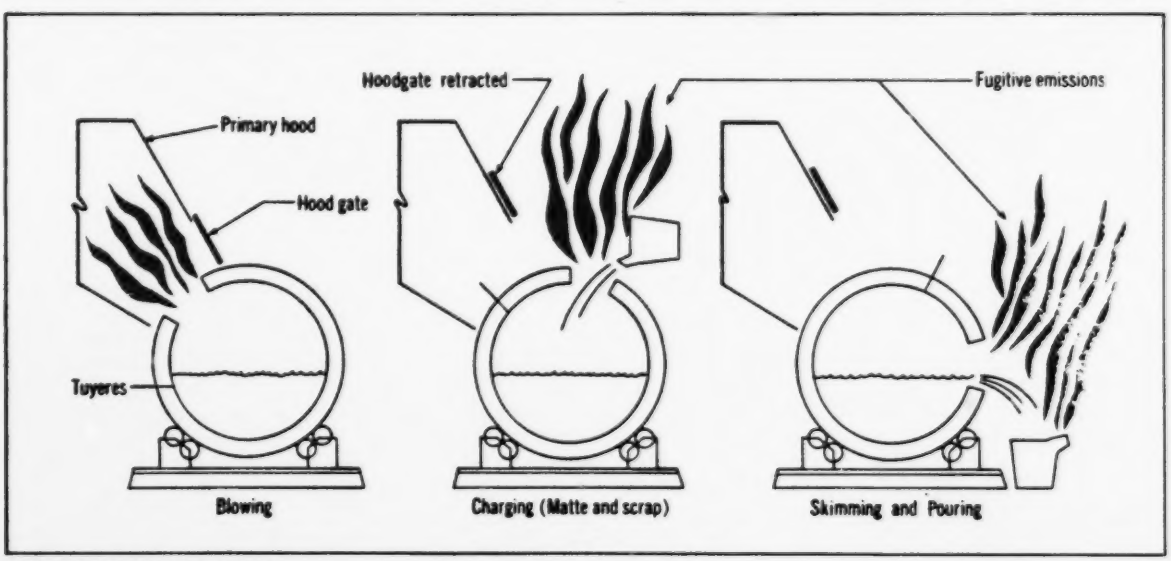
Characterization of the process fugitive particulate source is necessary to design the hood type selected. Among the important source parameters are continuous or intermittent plume, plume flow rate, plume geometry, source heat flux, source geometry, physical/chemical characteristics of the particulate matter (especially particulate concentration), gas composition, gas temperature, and layout of the plant. For existing sites, these source parameters may be measured directly. For planned sites, values of the source parameters might be estimated, or data from similar plants may be used.

Design methods use the source parameter values above in various ways to obtain the necessary exhaust rate and dimensions of the hood. Any one or combination of five different design methods may be used. In increasing order of sophistication, they are:

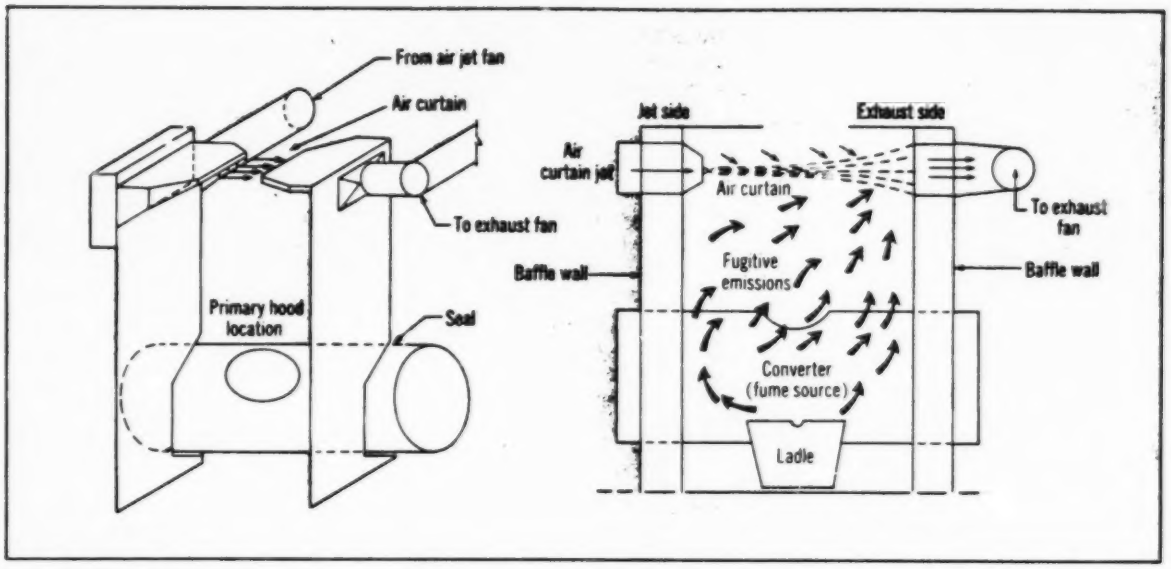
- Design by precedent.
- Design by rule-of-thumb.
- Design by analytical methods.
- Design by diagnosis of an existing site.
- Design by physical scale model.

In design by precedent, a working hood system that performs satisfactorily is copied. Although this method is simple, it can be powerful in producing a design that performs well. However, in using this method, working designs that use excessive exhaust, and are therefore overdesigned, may be copied. Failures using this method result because the copied system does not match the source parameters of the system under design.

In design by rule-of-thumb,




2 Copper converter operations.




3 Converter air curtain control system. *Courtesy of PEDCo. Environmental, Inc.*

working systems are surveyed, and the elements common to most of them are put together to form a working design rule(s). This method is straightforward, but the design rule(s) is likely to oversimplify matters and may result in unacceptable performance. Alternatively, following the design rule(s) may result in a hood system that performs satisfactorily but uses excessive exhaust.

Design by analytical methods uses a mathematical model to predict hood exhaust rate and dimensions from the source parameters. Examining hood systems is not necessarily part of this method.

Design by diagnosis of an existing system is more specialized than the other methods. An existing system usually is not performing satisfactorily. Extensive observations and measurements are made to assess the hood design. Depending on the results, certain remedies may be applied to the hood system, or an entirely new design may be necessary.

Lastly, design by physical scale model is the most sophisticated method and may be applied to existing or planned sites. The hood design is scaled hydrodynamically as a physical model using water or air as the test medium.

As mentioned above, truly successful hood designs not only meet their expected performance standards but also remain reliable. Hoods are often placed in severe environments and are subject to extreme shocks, mechanical and thermal. Corrosion and erosion of the hood may also be factors. Fabrication techniques and choice of materials for the hood system therefore must be considered carefully. Acceptance of the hood system by operation and maintenance personnel cannot be overemphasized for ensuring ultimate reliability of any hood system.

## Sample case

This sample case is of an air curtain system installed on a primary copper converter for capturing low level fugitive emissions. The installation is at ASARCO's Tacoma Smelter and is the first domestic full scale prototype air curtain hood on this type of application. The air curtain capture efficiency was evaluated during an extensive testing program by PEDCo Environmental, Inc.[2] The results of this program have been used to describe the hood performance in a later section of this article. The original air curtain design calculation was not available for assessment. A design approach is presented for an air curtain based on application of an analytical technique to the existing site.

Copper converting is the process of transforming copper matte produced by a smelting furnace into blister copper. A Peirce-Smith copper converter is used and consists of a horizontal refractory-lined steel cylinder (13 ft diameter by 30 ft long) with an opening in the center (the converter mouth). The converter vessel is rotated into various positions during its operation. Fig. 2 shows the converter positions for charging, blowing, and skimming.

During converter blowing, oxygen enriched air is passed through tuyeres into the shell interior. Emissions generated during blowing are captured by a primary hood and routed to a sulfur dioxide recovery plant. Fugitive emissions (not captured by the stationary primary hood) are generated during converter charging, skimming, and pouring. During a typical 12 hr con-

verter cycle, secondary emission occurrences can total 30 min with an average duration of 4 min each.

Copper matte and cold scrap are charged by an overhead crane and ladle (a box may be used for scrap). Emissions during charging of cold scrap are the most severe.

When the converter is rotated out for skimming and charging, the primary hood gate is raised, and injection of air continues until the molten bath level is below the tuyeres. Similarly, before the converter is rotated back to the blowing position, the air is turned on. During these converter movements, significant amounts of off-gases, blown out by the air, are released and contribute to the overall fugitive emissions.

The primary hood suction is switched off when air to the tuyeres is shut off. Therefore, no partial capture of fugitive emissions occurs through the primary hood.

*Air curtain hooding system*— Four basic methods of converter secondary emission capture exist. These methods include enclosures, push/pull systems (air curtains), movable hoods, and fixed hoods. Regarding effectiveness, reliability, cost, maintenance, and operating interference, push/pull systems have been shown superior.

The air curtain as applied to the converter uses the principle of blowing an air jet across the open space above the fugitive source. Contact between the rising fumes and the air jet causes the fumes to be directed to a suction plenum located directly opposite. Fig. 3 illustrates the copper converter air system.

*Regulatory standards*— Regulations affecting the control of fugitive emissions are under the jurisdiction of both the Occupational Safety and Health Administration and the Environmental Protection Agency.

Under OSHA regulations, the intent is to provide an in-plant working environment that is relatively free of contaminants. Without secondary emission control (with building ventilation as the only means of diluting contaminant emissions), personnel are regularly exposed to contaminant levels above the OSHA standards. The contaminants of concern are sulfur dioxide, copper dust, lead, and inorganic arsenic.

Under EPA regulations, the present intent is to maintain ambient air quality standards for sulfur dioxide. Sulfur dioxide ground level concentrations in violation of ambient standards can result from fumigation by converter fugitive emissions. Opacity regulations, which promote zero visible emissions from process buildings during all operating conditions, would also be violated by uncaptured fugitive particulate emissions.

Successful operation of a capture hood for converter secondary emissions certainly can satisfy indoor regulations and also ambient regulations if captured emissions are cleaned and/or dispersed to acceptable levels.

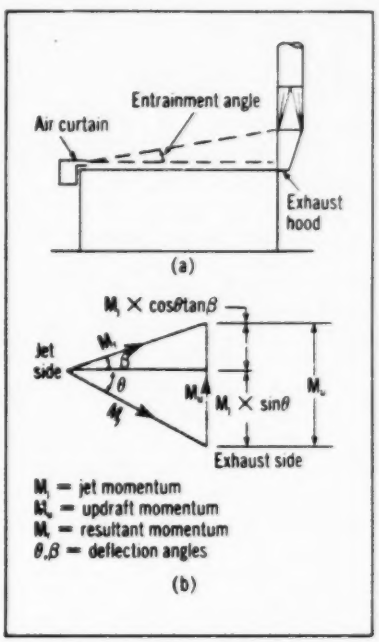
## Design approach

The original air curtain design calculation was not available for this assessment; therefore, the following design procedure is based on application of an analytical technique to the existing site. This same approach has been used successfully to design the air curtain hood component of various electric arc furnace enclosures.

The use of air jets in hood designs is not a new concept. This section is concerned with the use of air jets to direct a buoyant plume into an exterior hood arranged laterally to the source. The topic of air jets has been examined theoretically by Baturin,[3] practically by Hemeon,[4] and most recently in an excellent report by Yung *et al*.[5]

Some preliminary concepts and definitions need to be addressed first. A series of air jets, or continuous blowing slots, is called an "air curtain," and for this particular application an air curtain, not a single jet, is necessary to direct a buoyant plume. The term *air curtain* frequently provokes misconception that the air jets create a semisolid barrier that the fugitive particulate matter cannot cross. This notion is false.[4]

An air curtain acts by entraining surrounding air. When used above a buoyant source, the air curtain will entrain the contaminated air, resulting in a calculable concentration of particulate matter in the air curtain. If the exterior hood, arranged to act as a receiving hood for the air curtain, fails to provide either adequate exhaust or face area to accommodate the flow rate and width of the curtain at the hood face, then the contaminant will not be captured.




4 Assisted exterior hood for buoyant source and analysis.

An idealized, assisted exterior hood arrangement is shown in Fig. 4a. The design equations are derived from momentum considerations. This analysis is restricted to "jet throw distances" (equivalent to source width in this arrangement) less than six slot lengths, which can be taken as a practical limit. Beyond that distance, the shape of the jet becomes circular and is of limited use for hood cap-

ture. The applicable momentum diagram is shown in Fig. 4b. First, it should be recognized that momentum is conserved at every section away from the jet so that the total rate of air flow in the stream in relation to the primary flow from the nozzle is found by applying the following momentum conservation equation:

$$(\rho_0)(V_0^2)(A_0) = (\rho_x)(V_x^2)(A_x) \quad (1)$$

where

$\rho$ = jet air density; kg per cu m, lb per cu ft

$V$ = average jet velocity; mps, fps

$A$ = jet cross-sectional area; sq m, sq ft

$(\rho_0)(V_0^2)(A_0)$ = momentum flow rate at the nozzle; m-kg/sec$^2$, ft-lb/sec$^2$

$(\rho_x)(V_x^2)(A_x)$ = momentum flow rate at distance $x$ from the nozzle; m-kg/sec$^2$, ft-lb/sec$^2$

Considering the geometry shown in Fig. 4b, the required jet nozzle velocity may be found from the following equation:

$$V_j = V_u \sqrt{\frac{(A_u)(T_j)}{(A_j)(T_u)}} \times \frac{1}{C_H} \quad (2)$$

where

$V_u$ = average plume updraft velocity; mps, fps

$A_u$ = plume cross-section at intersection with jet; sq m, sq ft

$A_j$ = jet nozzle area; sq m, sq ft

$T_j$ = jet air temperature; K, R

$T_u$ = average plume air temperature; K, R

$C_H = (\cos\theta \times \tan\beta) + \sin\theta$

The entrained air volume at the exhaust hood is calculated by using the governing equation for a continuous slot or equivalent line jet:[6]

$Q_s = 0.88 \sqrt{(Q_j)(V_j)(X)}$,
(cu m/sec/unit length of slot, cu ft/sec/unit length of slot) (3)

where

$Q_s$ = hood suction rate; cu m/sec, cu ft/sec

$Q_j$ = jet nozzle flow rate; cu m/sec/unit length of slot, cu ft/sec/unit length of slot

$V_j$ = jet nozzle velocity; mps, fps

$X$ = entrainment distance; m, ft

The entrainment distance is usually taken as the distance between the nozzle and exterior hood. The entrainment angle of the jet, which defines the boundaries of the jet, has been found experimentally to have an approximate value of 24 deg.[6] Fig. 4a demonstrates that the minimum hood height is the entrainment distance multiplied by the tangent of the entrainment angle.

Recommended practices in the use of these equations are as follows. Because of the vector addition of forces, if the jet nozzle is directed horizontally, the resultant force always will be above the nozzle elevation. Consequently, the nozzle should be pointed downward at an angle of 15 to 25 deg from the horizontal. Air jet velocities at the nozzle should not exceed 30 m per sec to avoid excessive noise or energy consumption. Finally, the interaction of the air curtain and the exhaust hood can be complex, especially if the velocities of the suction field at the hood are of the same magnitude as the jet velocity values in the vicinity of the hood. Assisted exterior hood designs therefore often require considerable adjustments to the nozzle angles and slot widths to achieve acceptable performances.

## Design application

The first step of this design application requires determination of the emission plume flow rate and velocity. The air curtain is then located by careful consideration of fume source characteristics and converter operating requirements. The final air curtain configuration is determined by applying the theory of jet behavior from the above section.

Fig. 5 shows the fugitive emission plumes originating from charging and skimming activities with respect to the as-tested air curtain. The dimensions and location of the air curtain have been pieced together from sketchy information but are more than appropriate for verifying the air curtain design.

The volume and velocity of fumes rising to the air curtain level during charging and skimming are predicted by using the following relationships:

*Heat release*— Heat is released from the following locations:

- converter mouth
- hot metal stream
- surface and sides of the ladle

From fundamental heat transfer calculations, a heat release of approximately 150,000 Btu per min is determined for both charging and skimming. Buoyancy flux is calculated from:

$$F = \frac{(g)(q)}{(C_p)(T_u)(\rho_u)} \quad (4)$$

where

g = gravity constant, 32.2 ft/sec$^2$

q = heat transfer rate, Btu per min

$C_p$ = specific heat of air = 0.24 Btu per lb per deg F

$T_u$ = absolute air temperature, 530 R

$\rho_u$ = air density = 0.075 lb per cu ft

$$F = \frac{150{,}000 \times 32.2 \times 3600\ \text{sec}^2/\text{min}^2}{0.24 \times (460 + 70) \times 0.075}$$

The resulting buoyancy flux is $1.8 \times 10^9$ ft$^4$/min$^3$.

*Plume flow rate*— The vertical distance between the virtual plume origin and the air curtain elevation from Fig. 5 is 21 ft for charging and 38.5 ft for skimming. The plume flow rates are then calculated from:

$$Q = 0.166\,(Z)^{5/3}\,(F)^{1/3} \quad (5)$$

where

$Q$ = plume flow rate at the hood face, acfm

$Z$ = effective height from the virtual plume origin to the hood face, ft

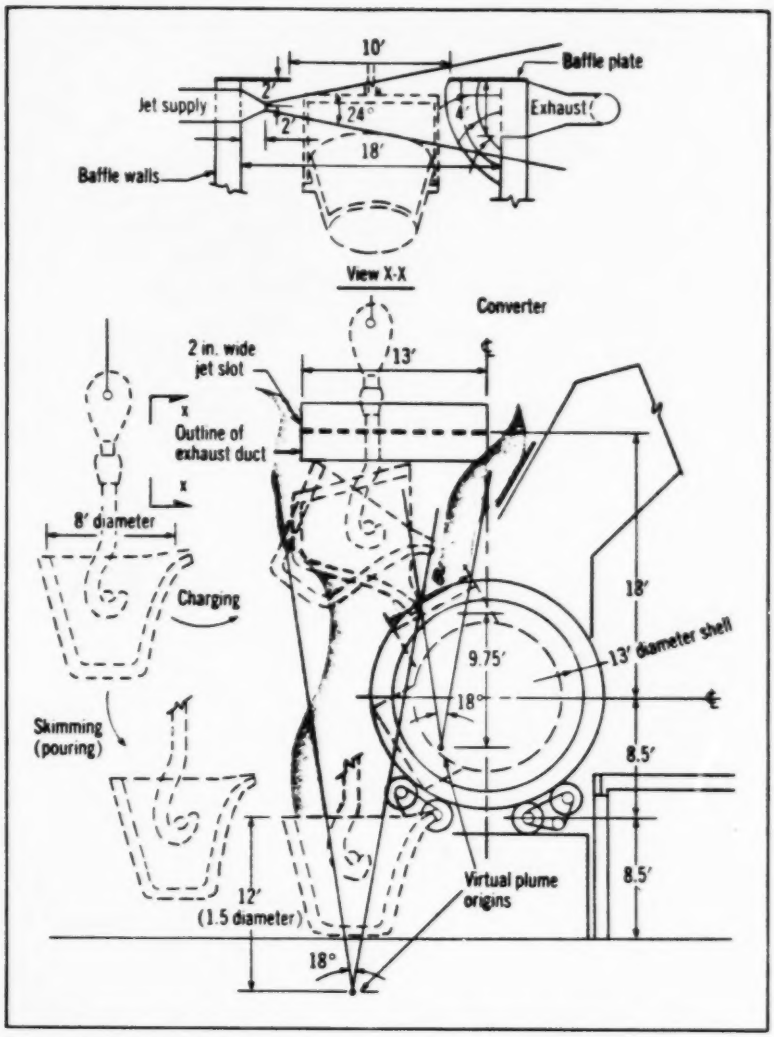
$F$ = buoyancy flux, ft$^4$/min$^3$

charging: $Q$ = 32,000 acfm at $T$ = 480 F

skimming: $Q$ = 90,000 acfm at $T$ = 185 F

$T$ is calculated by a simple heat balance on the plume volume.

*Plume velocity*— The mean velocity of the rising air column at the intersection with the jet elevation is found by:




5 Analysis of air curtain system.

$V = Q \div A$ (plume cross-sectional area at the jet elevation).

For *charging*, the plume will spread around the ladle as it rises, and the cross-sectional area is based on a diameter of 10 ft (an ideal plume with an entrainment angle of 18 deg cannot be assumed):

$A = 10 \times 10 \times \frac{\pi}{4} = 79$ sq ft

$V = \frac{32{,}000}{79} = 410$ fpm

For *skimming*, the plume will spread under the influence of the hot converter shell, and a cross-sectional area based on a 15 ft diameter is assumed:

$A = 15 \times 15 \times \frac{\pi}{4} = 177$

$V = \frac{90{,}000}{177} = 510$ fpm $= 8.5$ fps

The above analytical approach can be supplemented with data collected from plume photography in the case of an existing site.

Equation 2 can be used to calculate the required jet velocity. For the present case (Fig. 5), assume Angle $\beta = 0$ (Fig. 4b). Set $\theta = 15$ deg, and assume the worst design case of skimming where $Q_u = 90{,}000$ acfm, $V_u = 8.5$ fps, $T_u = 185$ F, and $A_u = 176$ sq ft. Assuming the jet slot width and length from Fig. 5, and density, then:

Slot width = 2/12 ft

Slot length = 13 ft

$T_j$ = jet air at ambient temperature of 70 F (530 R)

$A_j = 2.166$ sq ft

From Equation 2, $V_j = 137$ fps = 8220 fpm; and $Q_j = 2.166 \times 8220 = 17{,}800$ acfm

This compares to 18,000 acfm for the nozzle velocity on the as tested prototype air curtain.

Next, the entrained air volume and jet velocity at the receiving hood are calculated by the governing equation for a line jet. Volume flow rate at distance $R$ from the slot is represented by $Q_H$ and is estimated by Equation 3:

$$Q_H = 0.88\,[(Q_j)(V_j) \times (R/\text{slot length})]^{1/2} \times (\text{slot length})$$

where

$Q_H$ = plume arriving at hood face, acfm

$Q_j$ = jet flow rate at origin, acfm

$V_j$ = jet velocity at origin, fpm

$R$ = distance from slot, ft

The distance $R$ is established by considering the influence of the exhaust plenum capture zone and the baffle plate. Entrainment is judged to occur between the jet and the edge of the baffle plate on the exhaust side. Beyond that point, entrainment is blocked by the upper baffle plate, and the plume updraft is captured by the influence of the exhaust off-take velocity field.

From Fig. 5, $R = 12$ ft; therefore:

$Q_H = 0.88 \times [(17{,}800/13) \times 8200 \times 12]^{1/2} \times 13 = 133{,}000$ acfm

To capture all the entrained air, the minimum exhaust volume will have to be 133,000 acfm. The hood as tested exhausts 126,000 acfm.

Using the above equation requires the assumption of a small density difference between the jet air and the air being entrained. In this case the average updraft temperature, estimated to be 185 F as compared to jet air assumed to be at an ambient temperature of 70 F, yields densities of 0.062 and 0.075 lb per cu ft, respectively, or a difference of about 20 percent. The esti-

Table 1—Summary of hood capture performance.

| Operating mode | Hood capture efficiency, percent, by tracer gas study | | Hood capture efficiency, percent, by visual observation of opacity | | Measured opacity, percent, above hood | Sulfur dioxide emission | |
|---|---|---|---|---|---|---|---|
| | A | B | Observer 1 | Observer 2 | | Average, lb/event | Average, lb/min |
| Matte charge | 94 | 62 | 94 | 91 | 14 | 9.5 | 2.19 |
| Cold additions | 99 | 62 | 95 | 85 | 21 | 32.0 | 7.38 |
| Slag skimming | 95 | 84 | 78 | 82 | 18 | 11.0 | 2.35 |
| Copper pour | 89 | 81 | 92 | 85 | 9 | 7.4 | 1.94 |
| Rotate in/rotate out | — | — | 77 | 76 | — | 23.0 | 6.15 |
| Blow/idle | 96 | 44 | 96 | 90 | — | 3.5 | 0.14 |
| **Overall** | **94.6** | **66.6** | **88.7** | **84.8** | **15.5** | — | — |

A = Tracer gas injection in upper control volume

B = Tracer gas injection in lower control volume

Note: Injection points in the lower control volume were immediately above or below the converter during charging, skimming, and pouring. Injection points in the upper control volumes were in the zone beginning above the converter and ending just below the exhaust hood face.

*Adapted from PEDCo Environmental, Inc. (1984).*

Table 2—Metric equivalents.

| English | Times | Metric yield |
|---|---|---|
| deg F | 5/9 | deg C |
| F/min | 0.556 | C/min |
| ton | 907 | kg |
| lb | 0.454 | kg |
| Btu/lb-F | 1.0 | cal/g-C |
| Btu/min | 252 | cal/min |
| cfm | 1.7 | $m^3$/hr |
| ft | 0.30 | m |
| sq ft | 0.093 | $m^2$ |
| cu ft | 28.32 | L |
| fpm | 0.00508 | m/sec |
| in | 2.54 | cm |

mate of $Q_H$ is therefore approximate. The core of the jet contains most of the intercepted fugitive gas, while the top fringe contains clean air; therefore, a partial exhaust of only 80 percent may be necessary for effective capture of fugitives.

By applying different nozzle angles and adjusting slot width, one can optimize the overall design with respect to minimizing jet and exhaust capacities.

## Performance

Estimates of the air curtain capture efficiency and fugitive emission factors for the overall converter cycle and specific operational modes were performed by PEDCo Environmental, Inc., under U.S. EPA Contracts No. 68-03-2924 and 68-02-3546.

Three separate converter cycles were evaluated during the extensive test program. Hood capture efficiency was evaluated by three methods: tracer gas study, visual observations of opacity, and measurement of opacity. Fugitive emission factors were developed from measurements on emissions captured by the hood for the following: sulfur dioxide, particulate, selected trace elements, and particle size distribution. Table 1 summarizes the various hood capture efficiencies and the $SO_2$ fugitive emission factor for the overall cycle and specific modes that are pertinent for assessing the hood capture performance.

The main conclusions reached by the test program with respect to hood capture performance are:

- A 90 percent or better fugitive emission capture was claimed achievable for the overall converter cycle and specific operating modes.
- Converter and crane operations are significant variables in the generation and capture of fugitive emissions.
- The fugitive emission generation rate is significantly greater during cold additions and rotating-in/rotating-out operating modes.

The information contained in this article is adapted from the U.S. Environmental Protection Agency, *Technical Manual: Hood System Capture of Process Fugitive Particulate Emissions,*[7] a reference guide on the design and evaluation of hood systems to capture process fugitive particulate emissions. Ω

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*This article has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.